surfaces; on weathered surfaces the bedding planes of the tuff, the faint outlines of blocks in the breccia may show up. This sim ity in appearance between the metamorphosed volcanic rocks and intrusive rock is to be expected, of course, inasmuch as the pyrocl rocks are made up principally of andesitic, and perhaps a little lat debris and have a very fine-grained matrix. Because of this similar it is very difficult to locate within a hundred feet the contact of north side of the Ophir Needles body. Farther from the intrusi the breccia beds are lighter colored and distinctly greenish, becaus the presence of considerable amounts of light-green epidote.

The groundmass of the flows of the Eureka, and presumably of other flow rocks, has been recrystallized to a microgranular aggreg near the intrusive masses, and the flow-banded character visible in glass or devitrified glass is lost. Near intrusions the phenocrysts feldspar, which are normally clouded with sericite and other miner have been recrystallized into fresh feldspar. Secondary chlori which had replaced the mafic minerals in the unmetamorphosed roc was recrystallized to fine-grained pyroxene near the intrusions and epidote farther away. Near Ophir Pass, the rocks between the upp part of the San Juan breccia and the top of the Burns latite conta considerable amounts of epidote, which apparently formed before t abundant silica and pyrite in this area was introduced.

Little change can be observed around the quartz-feldspar porphy plugs because most of these intrusions are in the area of later inten hydrothermal alteration that has destroyed any observable change

Little change in the wall rocks could be detected along the maf dikes beyond a slight hardening, probably caused by incipient re crystallization. Hardened breccia is commonly more resistant to ero sion than the unaltered breccia or the dike rock, so that in places i stands out along the margins of a dike.

QUATERNARY DEPOSITS

A wide variety of unconsolidated material covers the bedrock in much of the mapped area. In addition to the widespread soil and vegetation, much talus and coarse rock-stream material, landslide de bris, fanglomerate, alluvium, and a little glacial drift blanket large parts of the area. Because of the necessity of generalizing on the geologic map (pl. 16), these different types of surficial deposits are consolidated into two groups. The material shown as alluvium is mainly stream-laid material but includes some talus and glacial deposits; the talus includes all other types of unconsolidated cover, as well as some small local areas of alluvium.

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LANDSLIDES

Landslides are numerous in the area mapped, as might be expected in a region where deep canyons have been cut by glaciation, and where weak formations are interbedded with strong ones. Most of the landslides have occurred where the conglomerate of the Telluride formation and the overlying volcanic rocks overlie either the weak Brushy Basin member of the Morrison formation, or the very weak Mancos shale.

The large Silver Mountain landslide, which in effect forms the west edge of the mapped area, probably is the largest single landslide mass in the country. It has been studied and described by Cross and Puprington (1899, fig. 10, and p. 11) and by Ernest Howe (1909, p. 17–21). According to Cross and Purington (p. 11),

> The topography within this area is that most naturally characteristic of a surface made up of landslide blocks * * *. There are a great number of knolls, longitudinal ridges, or benches, the majority of which have steep outer slopes, with trenches, or depressions, often containing a stagnant pool, back of them, on the mountain side, and the drainage is extremely irregular * * *. While this area is large it exhibits relatively few exposures in which the attitude of the bedded formations there present can be clearly seen * * *. [In places] the tuffs strike somewhat west of north and dip * * * easterly * * *. [The upper edge of the slide] is not sharply indicated, except that above it are seen nearly continuous outcrops of the San Juan tuff in normal position and below it the confused landslide topography begins. On the west slope of Gold Hill, however, lateral ridges with a trench back of them, are found in several places near the cliffs of the San Juan. In some of these ridges the outcrops show the San Juan tuff dipping at various decided angles toward Gold Hill * * *. Rhyolitic debris [of the Potosi volcanic series] is scattered over the upper part of the slide area * * *. San Juan tuff and agglomerate forms most of the knolls and benches down to a level somewhat below 10,500 feet.

According to Ernest Howe (1909, p. 18) "It now seems probable that the Silver Mountain landslide * * * antedates in part the recent glaciation." Along the mountain front south of the Gold King Basin, however, several large masses of volcanic breccia have slumped since the area was glaciated. Some of these slides took place long enough ago so that they now are covered with soil and vegetation, whereas others are so recent that they are essentially free of vegetation. Bald Mountain and the ridge to the southeast that connects it with the main mountain front does not seem to have moved down, as the lowest exposed tuff beds of the San Juan breccia are at about the expected normal altitude.

Several somewhat smaller landslides occur along Bear Creek. Much of the upper part of the ridge east of the mouth of the canyon is covered by landslide material, from the altitude of the Wanakah formation up to the talus below the San Juan breccia. The Telluride forma-

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tion is involved in the landslide where it is shown covered by ta

A little farther south a landslide mass occupies most of the area 16) extending from the contact of the outcrop and talus 200 feet nc of the Champion mine, 1,200 feet north to the Telluride and San J outcrops, and from the Dolores outcrop northwest of the Champ mine eastward to the point of talus north of the Weller mine. T mass has been little modified by erosion or vegetative cover, althou from its lower edge a large amount of talus has gone down over Dolores cliff. Its surface is very rough, and it contains some blocks conglomerate hundreds of feet across. The position of the conglo erate and of a narrow basic dike in the mass northwest of the Cha pion mine shows that no great displacement is involved.

On the west side of Bear Creek a small landslide lies between t Contention mine and the Cutler outcrop to the east; part of it m have extended farther to the northeast almost down to the creek, b the area is now covered by talus and forest. The small flat below tl Contention mine probably represents the upper part of the landsli mass. From a little way south of the Contention mine, south to tl gulch north of the Canton mine, considerable landslide material li between the cliff of the Telluride formation and the general altituc of the Cutler formation. Most of this material is covered by talu soil, and vegetation. Large blocks of conglomerate, lack of outcrop and the broken-up nature of the Mesozoic rocks are evidence of thi landslide.

High on the east side of Gold Hill, southwest of the Nellie mine, mass of San Juan breccia is broken up by slumping and grades down ward into a large talus derived from it; its upper limit correspond closely with a zone of altered rock along a north-northwestward-striking fracture.

TALUS AND ROCK STREAMS

Two types of unconsolidated deposits are widespread in the South Telluride area—talus and rock streams. They are prominent geologic features. They have an important bearing on any discussion of the geology and mineral deposits of the area as they cover much of the bed-rock geology, and they restrict the location of mining operations, or make them difficult. Movement of talus may ruin or entirely wipe out trails, roads, or mining facilities.

The lower parts of many canyons and cirques are covered by deep layers of slide rock, and material falling from the stronger cliff-forming units buries many of the weaker layers in the section. The water-laid tuffs at the base of the San Juan breccia, the lower fissile part of the Burns latite flows (in some places almost the whole Burns latite), the gray latite flow and red latite flows and breccia of the Potosi vol-

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canic series are commonly obscured by debris from overlying layers. The talus is particularly extensive on the north side of the valley of Howard Fork and in many places extends nearly to the top of the main ridge.

The talus has been forming since the glaciers receded. At the lower altitudes much of it is stabilized and covered with vegetation and some soil; in other places it is forming rather slowly, and so little movement is taking place that the lichen cover on the blocks is undisturbed. At higher altitudes, however, especially at or above timberline, the talus is being deposited rapidly, and consists of fresh material in relatively unstable equilibrium. In those places where the volcanic formations below the Potosi volcanic series form many cliffs, fragments both large and small can be heard falling intermittently all through the day; the largest numbers fall in the mornings, however, when the sun melts the ice that forms almost every night at high altitudes. The falling rocks generally bounce off the cliffs and land out on the talus, and the safest place to make traverses is therefore right at the base of the cliffs. The narrow chutes along faults, dikes, and altered zones through the cliffs deliver a great deal of material to the taluses.

The active taluses are surprisingly steep, especially in areas where much material from the San Juan breccia is available. Apparently a considerable amount of fine, claylike material is derived from the breccia and this acts as a binder for the coarser material; in addition, it is believed that much of this claylike material is almost permanently frozen. The result is that the angle of repose of many large taluses is between 38° and 41°, and the angle of repose of several fairly large areas is as great as 44° to 45°.

Rock streams, sometimes called rock glaciers, are abundant in the area. At least 62, combining all the types discussed below, have been counted in the area, and there undoubtedly are more, covered by vegetation and soil. These rock streams consist essentially of slide rock which has moved from its original place of deposition. A rock stream may be recognized by its front, which is debris derived from the rock stream itself, by the slope of the top of the mass, which is much less than the angle of rest for talus, by the concentric ridges and troughs on it, and by ridges parallel to the direction of movement.

Some of the rock streams are ridges of detritus, either parallel to, but somewhat higher than, the foot of a talus, or crescent-shaped masses near the foot of talus, with the outer upper edge higher than the talus slope on each side, and, generally, a slight depression in back of it. Other rock streams occur as long ridges going down gulches and cross flatter ground, standing somewhat above the talus on each side. Still other rock streams are a combination of several types;

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good examples of composite rock streams are in the east side Palmyra Basin, in Grays Basin, and in the northeast corner of E Fork Basin.

GLACIAL DEPOSITS

The area covered by this report was eroded by glaciers duri Pleistocene time, and most of the material removed was deposit outside the area. The main terminal moraines must have been bel the junction of the South Fork and the main stem of the San Migu River (Atwood and Mather, 1932, pl. 3). Some glacially deposit material remains in the area, however, but it is spread rather thin and is not obvious because much of it is covered by talus and veget tion. No attempt was made to study or map it.

Some lateral moraine probably lies along Bridal Veil and Be Creeks, the Howard Fork, and the main stem of the San Miguel Rive A few masses of moraine were noticed in Bridal Veil Basin; th largest is the mass in which the portal and first part of the adit of th Little Dorrit mine is located. The hummocky topography belo Bridal Veil Falls probably is in part on moraine.

On the west side of the map area considerable amounts of moraina material lie in the lower parts of Prospect, Palmyra, and Gold Kin Basins, but it is not obvious because it lies on landslide topograph and is largely concealed by a heavy vegetative cover. The three Alt Lakes probably are dammed by small terminal moraines. At least some of the ponds and undrained depressions southwest and west of the Gold King Basin are on morainal material.

ALLUVIUM

As mapped, alluvium includes stream deposits, alluvial fan deposits, mud flow deposits, and iron oxide deposits. Stream deposits are usually found only along the flatter parts of the stream courses. Considerable amounts are along the Howard Fork and the San Miguel River; some alluvium is also shown in the flatter parts of Jackass Basin and lower Bridal Veil Basin. Actually, of course, much more lies along most of the streams than is shown. The flatter parts of most of the basins contain some marshy ground; it is mapped as a part of talus or outcrops. Some alluvium also occurs along Turkey and Prospect Creeks.

In the valley of Howard Fork the alluvial fans, mapped as alluvium, are deposited both by stream flow and by mudflows that come down the gulches. The fan from Spring Gulch, on which the town of Ophir stands, is the largest and has pushed the Howard Fork over against the south side of the valley. Elsewhere, along Bear and Bridal Veil Creeks, and along the main stem of the San Miguel River, the alluvial fans have been mapped as a part of the talus.

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Also included with alluvium are the deposits of iron oxide which occur north of Howard Fork between the mouths of Spring and Chapman Gulches. The largest occurs at Iron Springs, where several large terraces consisting mainly of iron oxide, with some clay and organic material, have been deposited by spring waters. Over a considerable area around the springs the coarse fanglomerate has been thoroughly cemented by the iron oxide. This large amount of iron oxide is probably derived by weathering of the pyrite disseminated through the large mass of hydrothermally altered rock that forms the whole mountainside to the north of the valley between Spring Gulch and a place east of Chapman Gulch.

SOIL AND VEGETATION

Much of the area is covered by soil and, at lower altitudes, by forest or brush, and above timberline, by grasses and annual vegetation. The soil over much of the country is immature and in many places consists mostly of frost-heaved rock plus creep material. Some better developed soil is found in the few flatter areas; such soils contain organic material in a few places where small patches of marsh occur. As mentioned before, much of the material marked as outcrop is partly covered by various thicknesses of immature soil.

GEOMORPHOLOGY

The present topography in the San Juan Mountains dates from Tertiary time, when a vast volcanic pile arose around the Silverton caldera. The youngest volcanic rocks in the area south of Telluride are a part of the Potosi volcanic series. According to Larsen and Cross (1956, p. 13) these rocks are overlain elsewhere in the San Juan Mountains by the Fisher quartz latite. Subsequent to the last volcanic activity a long period of erosion took place, and the San Juan peneplain of Atwood and Mather (1932, p. 21–26) was formed.

Only a few relic surfaces representing the San Juan peneplain are believed to be present in the South Telluride area. The largest one is a gently sloping area, rather deeply covered by soil, at altitudes between about 13,100 and 13,200 feet, between about 800 and 3,000 feet southwest of Bridal Peak. Other small areas of relatively gentle slope, such as that on La Junta Peak above about 13,200 feet, may be relics of the San Juan surface, but there are not many such remnants in this area. Somewhat lower and steeper upland surfaces may belong to the Florida cycle of erosion.

Consequent streams formed as the old-age surface was uplifted, and they flowed outward from the high volcanic center. In the South Telluride area these streams flowed westward and are represented now by the main stem and the Howard Fork of the San Miguel River.

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Between the time when the San Juan peneplain was uplifted and th beginning of the last (Wisconsin?) glacial stage, several glacial stage and interglacial erosion cycles occurred, according to Atwood an Mather (1932, p. 27–31). In a summary, referring to the whol San Juan region they say (Atwood and Mather, 1932, p. 31)—

In general there seem to have been two main cycles of erosion subsequent t that in which the San Juan peneplain was developed. The earlier of these the Florida cycle, progressed in general to the stage of late maturity befor the cycle was ended by crustal movement. The second cycle, the Canyon cycle is still in the stage of youth.

Normal stream erosion during Quaternary time has been interrupted at leas thrice by glaciation. The first of these glacial stages, the Cerro, occurred during the Florida cycle. The second and third, the Durango and Wisconsin, both took place during the Canyon cycle of erosion.

Little evidence of any glaciation previous to the Wisconsin stage was seen south of Telluride, but the Florida cycle of erosion is evidenced by the "broad outer valley * * * [of the San Miguel] 8 to 15 miles wide and 1,000 to 2,000 feet deep" (Atwood and Mather, 1932, p. 51), and by the presence of many smooth, moderately sloping upland surfaces above the steep cliffs cut by glaciers. They generally are soil covered, and generally lie at intermediate altitudes as sloping benches between the peaks and ridges (which may be close to the altitudes of the San Juan peneplain, now largely removed) and the glacially cut cliffs around the cirques and canyons.

Probable remnants of the Florida erosion cycle are listed below according to approximate locations and altitudes.

North (11,800–12,300) and south (11,800–12,200) of Gold King Basin.

North (11,600–12,270) of Palmyra Basin out as far as, and probably including, Bald Mountain (a higher interval to the southeast, and lower one at the northwest end of the ridge).

From the broad pass (12,600) south of Gold Hill (12,738) northward to and beyond Green Cone (11,903) including the slopes down to about 11,000 at the north end.

The west side of the ridge on the west side of La Junta Basin (12,400 to 13,200).

La Junta Peak, between altitudes 12,600 and 13,200 and most of the upper, smoothly sloping parts of the ridge north to Ballard Mountain (12,804).

The more gently sloping areas of the upper parts of the ridges north of Silver Lake Basin, north and south of Jackass Basin, north and south of Grays Basin, and south of Mud Lake Basin.

By the begining of the Wisconsin stage of glaciation, the Canyon cycle of erosion (Atwood and Mather, 1932, p. 29), as well as the two previous glaciations, had left considerable relief in the South Telluride area; the total relief probably was approximately 4,000 feet, not greatly different from that at present.

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The topography of the area between the San Miguel River and the Howard Fork shows considerable asymmetry with regard to the divide between the tributary streams respectively draining into the two main streams; the divide is in general about three times as far from the main stem as from the Howard Fork. It seems unlikely that this asymmetry can be related to the resistance to erosion of the bedrock, inasmuch as the largest mass of strongly altered, and apparently less resistant, rock in the whole area occurs between the Howard Fork and the divide to the north. Nor is it believed possible that the last glaciation could have done the amount of erosion necessary to produce so much asymmetry. Therefore, it is believed that most of the asymmetry of the drainage pattern was developed during the Cerro and Durango stages of glaciation. Presumably larger, and therefore more active, glaciers formed on northward-facing than on southward-facing slopes.

WISCONSIN GLACIATION

Wisconsin glaciers were important factors in the development of the present topography. Glaciation was intense and produced a fretted upland. The maximum extent of the ice is shown by Atwood and Mather (1932, pl. 3). The Bridal Veil glacier joined those coming down from the basins of Ingram, Marshall, and the other creeks north of the San Miguel River to form the large San Miguel glacier; farther down the canyon the Bear Creek glacier joined the main stream of ice. The Howard Fork glacier joined the one in the Lake Fork canyon, continued down the South Fork canyon, blended with the Bilk glacier (Atwood and Mather, 1932, pl. 3 and p. 72), and joined the San Miguel glacier; the terminus of the combined glacier was a short distance below the mouth of Deep Creek (to the northwest, off the map of this report).

Glaciation in the South Telluride area developed the features common to alpine glaciation, although these features are somewhat different from those developed in granitic or metamorphic terranes because of the influence of flat-lying lithologic units of differing resistance to erosion. The main upper basins of Bridal Veil Creek and the east fork of Bear Creek are compound cirques with several rock steps. Lena, La Junta, Silver Lake, Jackass, Grays, Mud Lake, and East Basins are tributary cirques, generally with several rock steps, which overhang the main canyons; all but Jackass, La Junta, and Grays Basins contain tarns. Most of the tarns are small, less than 7 acres in extent, but Blue Lake in East Basin is a large, deep body of water approximately 51 acres in extent when full. There are also numerous other ponds and marshes in the compound cirques, the largest of

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which is Lewis Lake. The level of many of the lakes and ponds the Bridal Veil drainage area has been raised by dams. Many, b not all, of the upper parts of the rock steps in the cirques are tl outcrops of the more resistant parts of the formations; the thinne less resistant parts are covered by talus at the bottom of the rock step

The cirque of Deertrail Basin forms the head of a small hangin valley which falls directly into the canyon of the San Miguel Rive West of the mouth of Bear Creek two incipient cirques cut the sout wall of the canyon, their lips standing at about 9,800 feet. Alon the west front of the mountains three small cirques form the uppe part of Prospect Basin, and two larger cirques, Palmyra Basin an Gold King Basin, lie at the head of Turkey Creek and Gold Creek Several tarns occupy these cirques. The three Alta lakes in Palmyr Basin lie in part on landslide material and are moraine-dammed features.

The part of the valley of Howard Fork within the mapped area has few typical cirques except for the large basin at the east end of the main valley, which contains Beaver Lake. The head of Staatsburg Basin is a fairly typical cirque; Spring Gulch is U-shaped and comes into the main valley nearly at grade. The rest of the gulches, however, have only a slight fanning out at their upper ends to show the results of glaciation. This is partly because the main canyon was filled with ice nearly up to the divide (Atwood and Mather, 1932, pl. 3) so that cirques formed on this south-facing slope probably only during the waning stages of glaciation, and partly because the weakly resistant character of the rock there has caused the oversteepened headwalls to slump down, forming extensive taluses.

All the main ridges above 13,000 feet are narrow jagged aretes and cols, and most of the peaks in the area are horns.

As the terminus of the main glacier fed by the tributary glaciers is outside the map area, little moraine is found in the area except for a little widespread material. The three glaciers in Gold King, Palmyra, and Prospect Basins did not join the main San Miguel glacier, however, and so deposited their moraines at the mouths of the respective basins; that is, on the upper edge of the Silver Mountain landslide.

POSTGLACIAL EVENTS

The several different geomorphic processes that have worked on the surface since the last glacial stage are: weathering, both physical and chemical; mass-wasting, including the formation of landslides, talus, rock streams, and mudflows, as well as talus-creep and soil creep; and the movement of material by running water, both sheetwash and streams. Some of the processes will be discussed briefly.

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WEATHERING

Physical weathering consists principally of the alternate freezing and thawing of the water in fractures, which breaks up all exposed rocks. This process supplies abundant material for the taluses. The sound of much material coming down from the cliffs can be heard all summer long, as frost forms almost every night, and the process is therefore in operation all year long except during the coldest part of the winter when there is no thawing.

Normal chemical weathering, which is somewhat slowed up by the long period of cold weather, takes place everywhere, but more especially on the flatter surfaces. An accelerated type of chemical weathering takes place along the veins containing sulfides and over the masses of rock containing disseminated sulfides (mostly pyrite) that are present in certain areas. The acidic solutions formed by the oxidation of the sulfides, added to the other weathering agents, produces much deeper and more thorough alteration of the rocks. This is especially true north of Howard Fork where the effects of both physical and chemical weathering have been so intense that talus and soil cover extend almost to the top of the divide on the north side of the valley.

Mature soils are rare in the South Telluride area because of the relatively rapid movement of material. Soils approaching maturity may be found on a few flatter areas, such as the relics of the San Juan peneplain, and in the swampy areas in the basins. Elsewhere the soil is relatively immature.

MASS WASTING

In a region with so much relief, cliffs and steep slopes are so abundant that landslides are common, the formation of talus is continuous and widespread, many rock streams have formed from the talus, mudstreams flow almost every year, and the creep of talus and soil is active nearly everywhere as an important process in altering the topography.

LANDSLIDES

Landslides in the South Telluride area have been caused by oversteeping (generally resulting from glacial erosion) by the presence of weak shaly rocks underlying strong massive units, or, more commonly, by combinations of these two factors.

The large Silver Mountain landslide was formed when the South Fork of the San Miguel River had deepened its canyon sufficiently below the level of the thick black shale beds of the Mancos shale so that the weight of the overlying massive conglomerate (Telluride formation) and of the great thickness of volcanic rocks pushed out

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the shale to the west in successive great landslides. This happen first before the Wisconsin glacial stage, as parts of the landslide a overlain by moraine. According to Cross and Purington (1899, 10–11) and from evidence seen in the main Alta adit (eighth leve some movement is still going on.

All the landslides in lower Bear Creek canyon (p. 243) were cause by the oversteepening of the canyon by glacial erosion. Some a comparatively old, and may even be pre-Wisconsin in age, but th one north of the Champion mine (p. 244) is comparatively recen and has been little affected by erosion since it formed. The landslid south of the Nellie mine is also mostly due to glacial oversteepening as the rocks involved are all San Juan breccia, although hydrotherma alteration of the wall rocks along a weak vein may have helped b forming a line of weakness above the unstable mass of rock.

TALUS

The widespread taluses are the result mostly of physical weathering (freezing and thawing) of closely jointed flow rock and breccia. Enough claylike material is formed by chemical weathering for the matrix of the talus to be high in clay, and much of it is probably almost permanently frozen, especially where large deposits of talus stand with slopes as high as 45°. The formation of talus has been continuous since the end of the Wisconsin stage of glaciation. The large amount of talus available plus the presence of a frozen matrix in much of it is believed to have an important bearing on the origin of the rock streams.

ROCK STREAMS

Rock streams are abundant in the area, primarily because of the large amount of relief and the abundant talus. Most of the rock streams are found in cirques. Rock streams form when talus becomes unstable. Talus accumulates with maximum slopes ranging from 38° to 45°; this is possible because of the clay in the matrix, frozen at least in some places, and perhaps everywhere if rock streams are to form, and because the coarse material on the surface does not allow any but the largest blocks to roll far after falling from the cliffs. Possibly the matrix must be frozen for the slopes to stand at about 41° to 45°. Such high slopes of the talus result in unstable conditions which give rise to several different types of movement, and these different types of movement result in different types of rock streams. These are classified and discussed below:

1. Rock streams resulting from relatively slow creep.
   a. Creep of talus along a straight slope gives rise to a mass of material with a flatter slope out from the foot of the talus slope. This mass in places has a ridge of coarse material at its outer edge, which apparently

could arise only from having large blocks roll across the snowbank that commonly covers the lower part of the slope until the middle of the summer; this ridge is found only on north-facing slopes, and this type of deposit resulting from solifluction plus rock falls across a snowbank is relatively rare. An example lies at the foot of the talus southeast of Lewis Lake.

b. Rock streams may be formed by slow creep of talus for a considerable distance down a gulch or depression. The creeping movement is probably helped considerably by alternate freezing and thawing. This material may show slight transverse concentric ridges and troughs at its lower end. Numerous examples occur in the upper parts of the gulches coming down the north side of the Howard Fork valley. When more water is present during formation, this type probably grades into regular mudflows, which deposit their load at the bottom of the gulch to form fanglomerate; several of them are present along the Howard Fork.

2. Rock streams resulting from relatively fast movement as a single event.

a. Slump of material that moves rapidly for a relatively short distance, pushing up a single concentric ridge above its toe, and leaving a depression in the talus slope behind it. The depression generally is more or less obscured, however, as the continually falling debris soon starts to fill it. This type of rock stream is believed to result from the melting of some of the ice in the matrix, with the result that at a certain time a considerable amount of material slumps down the slope. Good examples of these "single event" slides are two near the head of Jackass Basin, two in Lena Basin, and one at the head of La Junta Basin.

b. Slump of material that moves some distance with considerable momentum. This type usually involves more material than that in 2a, and may go considerable distances over relatively flat ground and even cross small gullies. This type of rock stream, like that in 2a, is probably caused by the melting of the ice in the matrix. One on the south side of Palmyra Basin is relatively long, narrow, and high with steep sides. It crossed at an angle the longitudinal ridges of an older compound rock stream that had come down from the southeast corner of the basin.

3. Compound rock streams. "Compound" rock streams generally form by a combination of periodic rapid movement interspersed with slow creep. Commonly such rock streams show the effects of repeated successive surges of the 2b type, plus perhaps some 2a and 1b types. Accumulation of talus must be rapid, with repeated overloading occurring to bring about this type. The 1b type of movement may be continuing slowly at present in these compound rock streams.

Ernest Howe (1909, p. 52–54) believed that all or at least most of the rock streams resulted from the breaking up of solid landslide masses as they tumbled down. One mass having such an origin is on the northwest side of Palmyra Basin. This mass lies north of the middle one of the three Alta Lakes; it has a doubly lobate steep front, a low angle of slope back of the front, a relatively small talus behind it, and the hillside back of it is a bare, treeless scar, standing out in strong contrast to the soil- and vegetation-covered slopes on each side of it. The landslide north of the Champion mine

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(see p. 244) is also somewhat broken up, but does not resembl typical rock stream; it has no flat toe, the range in the size of blocks is extreme, it starts in a scar in bedrock, and the movemen relatively slight, considering the size of the mass. The author lieves, however, that all the other types of rock streams descri above resulted from either slow or fast movement of steep talu overloaded by the rapid deposition of material, and probably brou about in most types either by creep helped by alternate freezing a thawing (type 1) or by the melting of the frozen matrix (type and 3). Howe (1909, p. 54) quotes Salisbury as suggesting tl "some process analogous to solifluction" might account for "smal rock streams."

STRUCTURE

The geologic structures in the mapped area are the result of t periods of diastrophism. The earlier period may correspond in tin to the Laramide revolution, for it involved tilting and faulting th followed deposition of the Mancos shale of Cretaceous age and pr ceded the erosion that took place before the deposition of the Telluric formation of Oligocene(?) age. Most of the later deformation prol ably took place in late Tertiary time, as most of it occurred after th emplacement of the last intrusives that cut the Potosi volcanic serie of middle or late Tertiary age (Burbank, 1930, p. 192), but befor the development of the San Juan peneplain in late Pliocene time (At wood and Mather, 1932, p. 25). However, some of the faulting of thi period of deformation occurred before all of the intrusives had beer emplaced, as some dikes followed fractures on which there had beer previous movement. During this later period of diastrophism some blocks were tilted toward the east and many faults cut the area.

Some of the faults in the South Telluride area appear to be related to the formation of the Silverton caldera, to the east, whereas others are apparently related to the stresses involved during the formation of the intrusive centers in the valley of Howard Fork.

OLDER DEFORMATION

The rocks older than the Telluride formation had been tilted to the northwest before the erosion surface beneath the conglomerate was formed. Thus, the Telluride formation rests on part of the Dolores formation at Bridal Veil Falls and south of the Silver Chief mine on Bear Creek, whereas it rests on rocks of Morrison age near the mouth of Bear Creek. The progressive overlap of the Telluride formation across the truncated edges of the older formations is exposed along Bear Creek, and in the canyon of the San Miguel River east of Tel-

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luride. The dip of the Mesozoic rocks now ranges between 5° and 10° NW., but must have been slightly greater when the Telluride formation was deposited, as this formation, as well as the rest of the Tertiary section, has been tilted eastward about 5°.

West of Ophir Needles, the Telluride formation rests on the Mancos shale, but in the east end of the valley it rests on part of the Dolores formation, according to Cross and Purington (1899, Historical geology sheet). Marble of Pony Express(?) age dips 20° NW. at the Crown Point mine, but the dips of the Mesozoic beds must decrease farther east; otherwise rocks below the Dolores formation should be at the surface.

Only two faults were observed on which movement took place before Telluride time, but there are probably others. One fault is exposed south of the San Miguel River about 2,400 feet S. 35° W. from the Smuggler Union mill. It strikes N. 50° E. and dips 75° NW. The first period of movement was of a reverse nature, the northwest side moving updip 40 feet relative to the southeast side. In late Teritiary time the fault was reactivated and the northwest side moved down about 5 feet relatively. As a result the base of the Telluride formation is thrown relatively downward 5 feet on the northwest side, whereas the Mesozoic formations are thrown relatively downward 35 feet on the southeast side of the fault.

A second fault about 700 feet north-northeast of the Contention mine strikes about N. 50° W., dips 60° SW., and cuts rocks of the Wanakah and Morrison formations. This may be the same fault as the one that cuts the Cutler formation in La Junta Creek just east of Bear Creek. To the southeast, the Telluride formation at the lip of La Junta Basin is not cut by a fault, so this fault may well be one with only pre-Telluride movement.

YOUNGER DEFORMATION

Tertiary diastrophism resulted in a slight eastward tilting, toward the caldera, and the formation of a great number of fractures. The exact amount of eastward tilt is difficult to determine, because the surfaces on which most of the stratigraphic units were laid down are uneven, because the individual flows and breccia beds are of uneven thickness and probably had at least a slight initial dip westward, and because there are many small faults, which make true dip determinations over any great distance almost impossible. Dips to the east of as much as 10° were observed, and probably average about 5°.

The area of the report was cut by a great number of faults during this diastrophism. The displacement on most of them is less than 50 feet, is between 50 and 100 feet for some, and more than 100 feet for

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only a few. In general the fault pattern in the eastern half of area is strongly influenced by the structural pattern of the Silve caldera to the east. Faults radial to the caldera trend westward ac at least the eastern half of the area and faults concentric to the calc trend northeastward in the northeastern part of the area, and tur a more north-northeastward trend in the central part of the a Some north- and northwestward-trending faults are also present.

The faults of the southwestern and southern parts of the area pear to be influenced by the intrusive centers in the valley of How Fork. They trend mostly northwestward and northeastward, a generally have only small displacements. A few faults also tre northward. A large compound graben, which brings the Potosi v canic series down between masses of San Juan breccia, lies alo the west side, from Gold King Basin northward into the valley Prospect Creek. Most of the drainage area of Bear Creek is c partly by faults from the caldera and partly by faults from t Howard Fork intrusive center. The rocks at the east end of t valley of Howard Fork are involved in a series of horsts and grabe formed between westward- and west-northwestward-trending fault which suggests a zone of disturbance lying between the group c quartz-feldspar porphyry plugs in the east end of the valley and th Silverton caldera.

Many of the faults are intruded by dikes, most of the faults hav at least some hydrothermal alteration along them, and all the or deposits of any importance lie along them. As the fault systems ca be divided into different sets in different parts of the South Tellurid area, the area will be subdivided into sections for the purpose o discussing the structure. Some sections have rather indefinite boundaries, but their approximate location is shown on plate 17.

The eastern section includes the whole drainage area of Bridal Veil Creek, most of Deertrail and La Junta Basins, and the upper half of East Fork Basin. The western boundary of this section is rather indefinite, being a broad zone of faulting, which is called the Boundary Zone on plate 17.

The western section includes most of the drainage area of Bear Creek, except that part in the eastern section, and extends west to the limit of mapping (see pl. 17).

The southwestern section includes the area from the southwestern side of Prospect Basin south to the Ophir Needles intrusion and the top of the Telluride formation, west of the Spring Gulch zone (north of Howard Fork) and west of the Suffolk slump (pl. 17).

The southern section includes the north side of the valley of Howard Fork from Ophir Loop to Ophir Pass, except that part north of the

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Ophir Needles intrusion and the Telluride formation west of the Suffolk slump.

The structures of these areas will be described in general according to age, from oldest to youngest, although in many places the relative ages of intersecting structures were not determined. Many fractures along which altered rock or vein matter is present may or may not be faults. The definite determination of a fracture as a fault depends upon observing the offset of some recognizable unit, such as a stratigraphic unit, a dike or another fracture. Where no offset was found, the assumption has been made that any fracture that is reasonably continuous or that contains gouge, hydrothermally altered rock, or vein matter, has had at least some movement along it, and is, therefore, a fault.

EASTERN SECTION

In the eastern section fractures of the oldest set strike northwestward, dip at high angles to the southwest and have relatively little displacement. In several places fractures of this set are offset by faults belonging to other sets, thus providing evidence of relative ages. Fractures trending westward or a little north of west are younger than the northwestward-trending set, but they are cut by northward- and northeastward-trending faults. Fractures of this westward-trending set are the principal loci for the economically important veins. Dips on these fractures are steep. None of these fractures is itself continuous for more than a few thousand feet, but there is a tendency for these short segments to cluster in a group, and the resulting zone may be a mile or more long. Numerous northward-trending fractures are present in the eastern section, and a few show relative northward movement on the east side. The youngest structures in this section are the northeastward-trending faults. Almost all show relative downward movement of the southeast side.

The faults of the Boundary zone (pl. 17) are discussed separately as they are probably controlled by a major fracture in the pre-Tertiary rocks, and are not directly related to the structure of the Silverton caldera as most of the other sets of faults previously mentioned.

The northwestward-trending faults are relatively short and discontinuous except for the Millionaire zone (pl. 17). They strike between N. 30° W. and N. 60° W., and dip southwest between 52° and 82°. Relative downward movement is on the southwest side, from 10 to 35 feet. The Cliff fault (pl. 17), is downthrown 35 feet, the largest throw observed on such faults. The Millionaire zone is continuous across the eastern section, from Blue Lake through the cliffs south of the San Miguel River. The fault is somewhat irregular in course, and the dips to the southwest range from 60° to 80°. Where

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it cuts the Telluride formation at the mouth of Deertrail Basin places the rocks 30 feet downward on the southwest side. A som altered dike is present discontinuously along it, and large amou mineralized rock are present in some places. This fault is be to be one of the oldest in the section, both because of the prese dike material along it, and because of its relations with other f In the workings at altitude 12,175 on the Dividend vein (pl. 18, westward-striking Dividend vein cuts the dike on the Millionaire but is itself offset by renewed movement on this fault. North c San Miguel River the fault continues northward, with a dike an Alleghany vein along it (Burbank, 1941, map).

The westward-trending faults dip between 60° north or south vertical. In general, the principal faults north of the latitude of Lake dip north, those farther south dip to the south. The displ ment is rarely as much as 40 feet, and is generally not more than this amount.

The most continuous zone of westward-trending faults is Champion-Dividend zone (pl. 17). Between the Boundary zone Bridal Veil Creek this fault dips 60° to 80° N. and is downthr as much as 20 feet on the north side. East of Bridal Veil Creek dip changes through vertical to south, and the amount of downthr on the south increases going east; at the base of the cliffs on the e side of Grays Basin the offset is 5 feet but at the top of the ridge it 30 feet. The rest of the faults as far south as the latitude of the nor end of Blue Lake, including the La Junta-Royal fault zone and Orie fault zone, are more discontinuous than the Champion-Dividend zor Most of them, however, dip to the north.

South of the latitude of the north end of Blue Lake, the fractur striking approximately west are less abundant, and all apparentl dip to the south instead of to the north. The most prominent an continuous of these are the three faults of the Little Dorrit fault zone the middle one has a dike along part of its distance and has at least 4 feet of displacement. The most southward structure of this type is zone of weak fracturing, trending about N. 80° E. on the south sid of Lewis Lake.

These westward-trending fractures, although spaced more unevenly, are believed to be similar to the northwestward-trending faults in the Telluride-Sneffels area (Burbank, 1941, p. 215–227, and map) that radiate from the Silverton caldera. Most of these fractures in the South Telluride area however, are neither so continuous nor so regular in strike as those described by Burbank. Some of them can be grouped into zones that are fairly continuous across the eastern section and into the western section.

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Many fractures trending north or a little west of north are the next youngest set. Many of them have some mineralized rock along them and, toward the south, some contain veins. Some are faults having both a horizontal and a vertical component of displacement, the east side being moved relatively north and downward. The more continuous of these faults are grouped in two zones, the North Bridal zone and the South Bridal zone (pl. 17). The Little Dorrit and Lewis mines both lie on the South Bridal zone. As observed, the amount of horizontal displacement on individual faults is not great, (7 feet north of the Royal mine, 12 feet north of, and 60 feet south of the Little Dorrit mine), but with many such fractures present, the cumulative relative displacement of the rocks on the east side of the zones to the north may be considerable. How this northward movement of the rocks on the east is related to the origin of the Silverton caldera is not known.

Northeastward-trending faults are the youngest in the eastern section. All are between the Wasatch zone and the east side of the section. The faults of this set trend between N. 30°–50° E., and dip to the southeast. All are downthrown on the southeast side, generally from 20 to 50 feet, but the Pulaski fault has about 150 feet of displacement in places. Toward the south these faults have a more southward trend.

These northeast faults line up with structures to the northeast, which Burbank has grouped (Burbank, 1941, p. 157–158) as the concentric system of the caldera; that is, they apparenly are fractures out in the shield area parallel to the edge of the caldera, on which there was some movement sympathetic to the dropped block within the caldera.

Some northeastward-trending fractures in the southern part of Bridal Veil Basin are believed to belong to a different set of fractures, with a different origin than that described above for the concentric faults. This set, of which the Lewis zone (pl. 17) is a member, generally has a more eastward trend than the concentric faults, shows up as broad zones of shearing rather than as definite fault planes, and is probably tied in with a broad northeastward-trending group of fractures coming into Bridal Vein Basin from the central part of the valley of Howard Fork.

The Boundary zone of faulting has in general an average trend of S. 40° W. from north of the San Miguel River (about 500 feet east of the Smuggler Union mill) to the Weller mine, and of about S. 20° W. from the Weller mine to the divide on the north side of Howard Fork. Although these trends are similar to those of northeastward-trending concentric faults, this zone of faulting is more complicated,

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appears to limit some of the west-northwest fissures in the we section. and it lines up approximately with the Wheel of Fortune of the Telluride-Sneffels area to the northeast (Burbank, 1941, n which Burbank does not group with the concentric faults. More it is believed that this fault zone is relatively old, in contrast t concentric faults which are the youngest set of faults, both becau the pre-Telluride movement on one of the faults along it and bec of the presence of dikes along it. Burbank points out (1941, p. that the Wheel of Fortune fissure has both andesitic and rhyc dikes along it, which would also indicate relatively early faulting.

The Boundary zone (pl. 17) is fairly simple from south of the Miguel River to the west side of Deertrail Basin, consisting of main fault, one split from it, and another fault, 500 to 700 feet so east of the main fault. The general area around the Weller n (from the Champion mine to Ballard Peak) shows a complica structural pattern, apparently the result of the intersection of northeast zone of faulting and the Champion-Dividend westwa trending one. Here, several northwestward-trending fractures present in addition to the northeastward- and westward-trend fractures, both within the complicated area and trending to the sou east toward the La Junta mine as a group of faults. The main fa leaves the Weller area trending south, then turns about S. 30° across the lower La Junta Basin to the ridge on the west side of t basin; it shows as much as 50 feet of displacement downward on t east side. About 1,500 feet north of the Nellie-Wasatch zone the fa splits, turns south, and the amount of displacement decreases sout ward. Within La Junta Basin several splits from the main fault tre south across the basin. Southeast of the point where the main fau turns south, these southward-trending fractures become more prom nent, and continue south-southwestward through the ridge on tl west side of the basin; all show downward displacement on the ea side. A dike along the easternmost through-going fault extends fro upper La Junta Basin almost to the Highline mine on the south sid of the Howard Fork divide. On the south side of East Fork Basi the zone of faulting enters an area having a complicated structura pattern where it is joined by the concentric faults coming southwes from La Junta Peak. It is intersected by the Bear Creek fault. Th Boundary zone was not seen south of the Carbonero-Highline zone trending northeastward.

Possibly this whole Boundary zone of faulting overlies a fault or fault zone in the rocks underlying the Tertiary section, which was active in pre-Telluride time. The Wheel of Fortune vein to the north-

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east (Burbank, 1941, map) lies approximately along the same structural line. The broad zone of splitting fractures, having a roughly en echelon arrangement, may thus be a reflection in the Tertiary section of movement on a through-going fault in the pre-Tertiary rocks.

WESTERN SECTION

The western section has a few structures, trending northeastward and northward, more trending northwestward, and many trending west or west-northwestward. The age relations of the northeast and north and northwest fractures are confusing because of renewed movement along older fractures which had been filled with dikes, but most of these fractures appear to be older than the westward-trending fractures. One exception is the Bear Creek fault (pl. 17), which appears to be one of the youngest faults in the western section.

Of the few northeastward-trending fractures in the western section two have dikes along part of their extent, and of these only one, the Northeast Gold fault, has appreciable length and displacement on it. This fault has displacement as great as 30 feet downwards and 10 feet southwest on the northwest side. The other northeastward-trending fractures include a couple of faults seen cutting only the Mesozoic rocks along lower Bear Creek, and several relatively short ones with veins along them on the west side of the small flat where U.S.M.M. Delta is located. Although the Contention fault strikes about N. 75° E., this fracture probably belongs to the Champion-Dividend zone.

Three of the approximately northward-trending fractures occur in the south part of the western section; the only others in this section are a few fractures in and near the Champion mine, which may be minor northward branches of the boundary zone of faulting. Of the fractures in the south part of the section, the East Delta fault shows the greatest displacement, 100 feet downward on the east. The West Delta fault has only 18 to 20 feet of displacement downward on the east side; a dike lies along this fault discontinuously. The Lena fault trends across Lena Basin about N. 5° W. to the south end of Gold Hill, where it appears to die out; it has a dike most of the way along its extent, and shows only a small amount of displacement.

Three of the northwestward-trending fractures in the western section have dikes at least discontinuously along them, and four, of somewhat less extent, do not. The Green Cone fault has a dike along it, and shows only a small amount of displacement. The Fairview fault (pl. 17) shows 35 feet of displacement downward on the north side, and has a dike along it on the west side of the canyon; on the east side of the canyon it appears as only a relatively weak zone of fracturing, with no dike. The third fault with a dike along it in places is the San

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Joaquin fault, which cuts the east end of the Spring Gulch diorite at its south end. It is a scissor fault, showing 15 feet downwar placement on the west side, west of Gold Hill, and 22 feet down on the east side where it cuts into San Joaquin Ridge. The north ward-trending fractures without dikes in them are generally o extent. One northeast of the Contention mine has been menti already (p. 255). A northwestward-trending zone of fracturing the Canton fault southeast of Green Cone, and several fractures relatively little displacement are on Gold Hill and just east of it, tr ing parallel to the San Joaquin fault.

The westward- to west-northwestward-trending fractures are most abundant type in the western section, as well as the most im tant economically, as almost all the known ore deposits lie along th Most of them can be grouped into zones. From north to south tl are: (1) the Champion zone, which is alined with the Divid zone to the east; the Contention fault appears to lie in the same zo although it has a strike of about N. 75° E.; (2) a group of zones fr the Canton to the Silver Chief faults are alined with the zone fr the La Junta to the Royal faults to the east; (3) the Nellie-Wasa zone; (4) the Delta zone, which includes the westward-trending fr tures between 1,400 feet north and about 1,000 feet south of U.S.M. Delta; it is alined with the Little Dorrit zone to the east; (5) a zo on the south side of Lena Basin, which does not appear to be alin with any zone to the east. Almost all the fractures in these zones a faults dipping to the north, with downward displacement on t north side of from a few feet to as much as 40 feet. The fe exceptions are the western part of the Champion vein and the Sava zone of faults that show from 10 to 50 feet downward displaceme on the southwest side; in the Savage mine itself, however, the di is to the north. (See pl. 20*C*.)

The Bear Creek fault (pl. 17) appears to be the youngest fau in the western section, and everywhere shows downward displacemen of from 115 to 200 feet on the west side. Its actual intersection wit other faults was seen only in the Maryland mine (pl. 20*D*) wher it cuts the Maryland vein 530 feet in from the upper portal.

The fault zone taken as the west boundary of the western sectio between Prospect Basin and the divide south of Lena Basin is a singl fault (called the Spring Gulch zone on plate 17) where it crosses thi divide, but to the north it splits into several faults, some having a northwestward trend and others a northeastward trend. Near the point where the fault is covered by talus on the south side of Lena Basin it splits, and on the northwest side of Lena Basin and on the south side of Prospect Basin a complicated fault pattern is evident.

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Northward-trending fractures split off from the northwest faults, then trend northeast and disappear under the talus of Prospect Basin. Presumably they then turn again to the northwest down Prospect Basin, as none is seen in Gold Hill to the northeast.

The faults in the western section are possibly related both to the Silverton caldera and to the two intrusive centers to the south (pl.17). Many of the fractures trending northeast, north, or northwest are filled with dike material similar to that at the intrusive centers, and the other fractures parallel to these presumably have similar origins. The zones of westward- to west-northwestward-trending fractures, however, are alined fairly well with the westward-trending zones of fractures in the eastern section, which are radial to the caldera; in detail, however, many of the individual fractures do not cross the Boundary zone. The Bear Creek fault is not obviously related to either center of structural influence.

SOUTHWESTERN SECTION

The overall picture of the southwestern section shows a few northeastward-trending fractures across most of the block, a complex of fractures between Gold King Basin and the Ophir Needles intrusion trending in several directions, a group of northwestward-trending fractures on and just south of peak 13470 on Silver Mountain, and a compound graben-type structure extending northward from southwest of Gold King Basin across the lower part of Palmyra Basin and down Prospect Creek an unknown distance under the Silver Mountain landslide mass. The south end of the graben is bounded by a circular fault.

The complex group of fractures north of the Ophir Needles intrusion, many filled with dikes, as well as the northeastward-trending fractures that extend across the southwestern section, appear to be structurally related to the Ophir Needles intrusion. The northwestward-trending fractures of peak 13470 on Silver Mountain, on the other hand, extend outward from the west end of the oval Spring Gulch intrusion and are probably structurally related to that mass; these are economically, the most important fractures in this section, as they contain important ore bodies. In general the age relations of the fractures in the southwestern section seem to be: The complex of fractures north of the Ophir Needles and the northeastward-trending fractures are the oldest. Then the graben was formed. The northwestward-trending fractures of peak 13470 on Silver Mountain are the youngest as they cut both the northwestward-trending fractures and the graben.

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The older fractures of the complex north of the Ophir Needles the northeast fractures of the whole southwestern section were fil with dike material, and in general show the age relations, from old to youngest of northwest, west, and north and northeast. Renev movement on some of the older fractures after the intrusion of dikes and the formation of newer faults give no definite relation age in regard to direction. The dips are generally steep, in exc of 80° with many close to 90°, although a few are as low as 60°. T faults do not dip consistently in any one direction. The displacemer are not great, although in many places they are indeterminate becau only San Juan breccia is exposed on the surface. Apparent northwa movement as much as 25 feet on the west side of some of the nort ward-trending faults occurred. Vertical displacement as much as feet took place on other faults. One fault, which shows 160 feet displacement down on the west side on the ridge south of Gold Kin Basin, is believed to be part of the graben.

The graben is a compound structure within which several blocks ar separated by faults; the blocks are at altitudes much lower than in th rest of the area, and some are decidedly tilted. The structure is bes exposed on the ridge on the north side of Palmyra Basin, which ex tends out to Bald Mountain, and the eastern part of it is also expose in the ridge extending west-northwestward from Peak 13470 on Silve Mountain; what is probably the south end of the graben is exposed or the spur at the southwest edge of Gold King Basin, where a fault has 160 feet of displacement down on the west; just west of this fault a circular fault bounds an area that may be underlain by an igneous pipe of untrusive rock (see p. 238).

Along the ridge of the north side of Palmyra Basin, from a point 2,700 feet N. 66° E. from the portal of the St. Louis mine (4th level) toward Bald Mountain, the following structural units are exposed:

1. A graben of breccia and conglomerate of the Burns latite for 700 feet, dipping 15° to 30° west, and bounded on the west by a dike-filled southeastward-dipping fault.

2. A horst of San Juan breccia for about 1,100 feet, dipping about 40° northwest and divided by a southeastward-dipping fault into two blocks, the eastern one topped by flows of the Eureka rhyolite; the horst is bounded on the west by a northwestward-dipping fault having large downthrow on the northwest.

3. A graben of the Potosi volcanic series for approximately 2,300 feet, dipping northeast. A small patch of San Juan breccia, and flows and breccia of the Eureka rhyolite is faulted against the Potosi on the northeast side of the ridge. This graben is bounded on the west by

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a fault, nowhere exposed, which must have a displacement in excess of 1,500 feet downward on the east side.

4. The rest of the distance to Bald Mountain is underlain by San Juan breccia. Low on the west side of Bald Mountain, the lower water-laid tuff beds of the San Juan breccia are exposed at approximately the normal altitude, suggesting that this complex graben is therefore not related to the formation of the Silver Mountain landslide.

The ridge on the south side of Palmyra Basin shows only the first narrow graben, consisting mostly of Eureka rhyolite topped by a small patch of Burns latite. The fault on the west side of this graben has a dike along it. A large mass of San Juan breccia is topped by some flows and breccia of the Eureka rhyolite in the horst to the west. For the rest of the distance westward to the portal of the Alta mine, the graben, if present, is covered by landslide material or moraine. Surface and underground exposures show that two of the northwestward-striking faults in the country east of the graben (the Hancock and Alta) continue westward across the fault bounding the main graben on the southeast side.

The northwestward-trending group of fractures of peak 13470 on Silver Mountain includes, from north to south, the Palmyra, St. Louis, Hancock, and Alta zones (pl. 22) which contain ore deposits that are among the most important economically in the south Telluride area. Five of the factures contain dikes. All of them dip 55°–90° NE., except one, which passes about 200 feet north of peak 13470 on Silver Mountain. They show downward displacement on the northeast side of from a few feet to as much as 50 feet. A few of the fractures were filled with dike material and had little later movement, whereas most of them apparently were reopened by movement several times. There is some splitting and branching of the fractures, and the Alta zone consists of a number of separate fractures, some having an en echelon arrangement. This group of northwest fractures converges toward the west end of the elongate Spring Gulch intrusion and may represent a zone of weakness that partly guided the emplacement of the intrusive mass; none of the dikes or fractures appear to cut this intrusion.

SOUTHERN SECTION

Exposures are poor throughout most of the southern section east of the Ophir Needles intrusion, except for a narrow strip near the divide on the north side of the valley and the west side of Lookout Peak and Ophir Pass. Available surface and underground exposures, however, indicate that the northeastward- and northward-trending faults of the southwestern section are in the northern part of this section; the Spring Gulch fault (pl. 17), cuts across the southern section;

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in the central part of the section there is a broad northeastward-tren ing group of fractures that extend into the southern part of the easte section, and also a few westward-trending fractures; east of Cha man Gulch a number of northwestward- and westward-trending faul form a group of horsts and grabens called the Lookout group (plate 17; they may represent a zone of weakness or sagging betwe the area of quartz feldspar plugs in the central and eastern part (the valley and the Silverton caldera, whose southwest edge is abou 3 miles east of the Ophir Pass. Conversely, the group of horsts an grabens may be a reflection of the upward thrusting action of a possibl diorite mass underlying Ophir Pass.

The fracture systems in the western part of this section, and many o those in the southwestern section, may be related to the fracturin that controlled the Ophir Needles intrusion; this intrusion (Cros and Purington, 1899) extends a considerable distance south and south west of the area of this report. Likewise, the northeast zone of frac tures may represent a zone of movement extending between thi intrusion and the Silverton caldera to the northeast, the fracturing being probably more intense near the intrusion.

West of the Ophir Needles intrusion, only a few early-formed fractures are present in the narrow strip of metamorphosed Telluride formation and the underlying Mesozoic rocks. Most of them are filled with dike material and few have much hydrothermally altered rock along them. Only the edges of the intrusion were examined closely during mapping, but within it there are a few northeast fractures that line up with some in the southwestern section, and one dike-filled westward-trending fracture. East of the intrusion, few structures were mapped on the surface. Maps of the Crown Point and Santa Cruz mines and the Badger tunnel (pl. 21*D*, *G*, *J*) shows a few westward-, northward-, and northeastward-trending fractures.

The Spring Gulch fault is a single definite structure in the southern section, unlike the complicated fault zone northwest of Lena Basin. Just north of the Spring Gulch intrusion there has been 300 feet of displacement downward on the east side and about the same displacement near the mouth of the gulch where approximately the full thickness of the Telluride formation is faulted downward on the east.

Some fractures of the broad northeast zone are shown in the Badger tunnel, Gertrude, Carbonero, and Silver Tip mines (pl. 21*G*, *F*, *H*, *B*), in a few surface exposures northeast of the New Dominion mine (the Attica zone), and through and near the Highline mine (the Highline zone) (pl. 17). The northeast zone in the Calumet mine (pl. 21*C*) and those west of the peak (altitude 13,614 feet) may also belong to this northeast zone.

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At the east end of the Howard Fork valley westward- and west-northwestward-trending faults cut the area between the south end of Bridal Veil Basin and Ophir Pass into seven structural blocks, some of which are horsts or grabens. The net effect of the faults is that the rocks on the north side of the whole zone are down about 200 feet relative to the rocks of Ophir Pass. A few northward- or north-westward-trending faults are also in this zone.

The Suffolk slump (pl. 17) is a block of peculiar structure that lies between the Suffolk mine and Staatsburg Basin. The block is bounded on the west and northwest by the fault 300 feet west of the Suffolk mine, a fault that trends northeastward irregularly until it meets the fault on the west side of Staatsburg Gulch, which bounds the block on the northeast. The south boundary of this roughly wedge shaped block is probably the outcrop of the Telluride formation. Within this area the breccia and flows dip in a southward direction from 20° to 50° and the rocks are cut by a large number of faults with relatively small displacement, which dip between 35° and 45° NNW., and have hydrothermally altered rock along them (fig. 25). The change from essentially horizontal layers outside the block to the southward-dipping layers within the block is abrupt, although

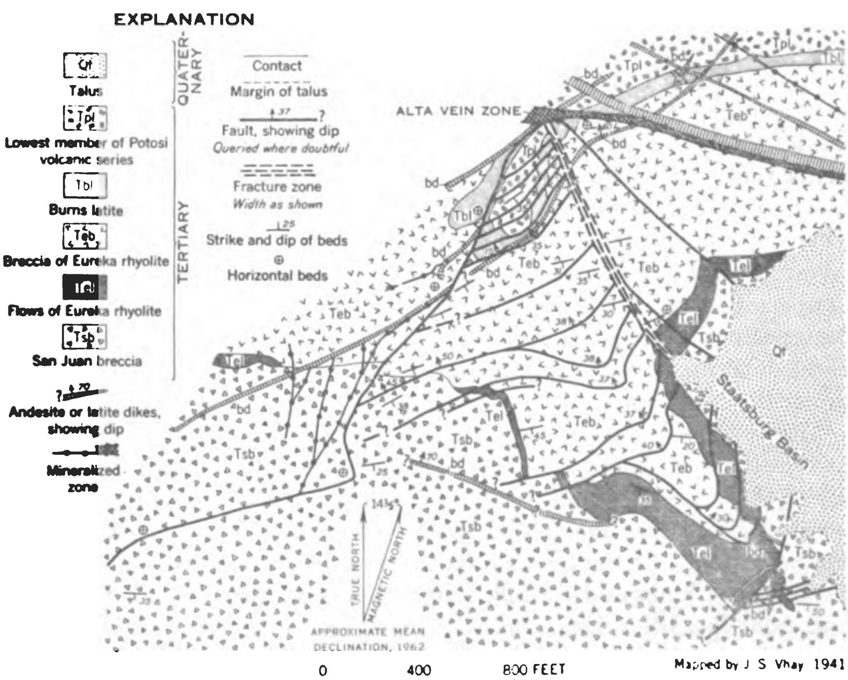

FIGURE 25.—Geologic map showing detail of structural complication in area between Suffolk mine and Staatsburg Basin.

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the boundary fault can be seen only at its northwest end in Staatsl Gulch, where it appears to be a relatively wide zone of closely sp fractures. The layers just outside the block appear to be drag down slightly, as they dip about 5° SE. near the fault zone. A tinctive porphyritic dike trending roughly east, about 100 feet sc of the Suffolk mine, is offset approximately 100 feet south from position in the undisturbed horizontal rocks to the west of the bou ing fault.

Inasmuch as it does not seem possible that this block is a landsl because of the presence of hydrothermally altered rock along faults within it, the block may have moved on a synthetic fault wh would crop out on the south side of the area just above the Tellur formation; the many small faults dipping north-northwest wo then be antithetic faults (Burbank, 1941, fig. 3). No reason can given, however, as to why this peculiar structure is located where is. Unlike the situation which Burbank describes for the R Mountain sag, the Telluride formation and the underlying me morphosed Mesozoic section are hard, relatively resistant rocks.

ORE DEPOSITS

Early mining in the South Telluride area was for the gold ai silver in the veins. Later, a few of the larger mines produced lea copper, and, more recently, zinc, but even these could not have ope ated at a profit were it not for the gold or silver, or both, that accon panies the base metals. Considerable gold was produced from quar veins that contained pyrite but no other minerals; a very few d posits of pyrite disseminated in intensely hydrothermally altered Sa Juan breccia were mined for gold. In most of the mines from whic silver was produced veins that contained galena and tetrahedrite (o freibergite) with sphalerite and chalcopyrite, in places, were worked gangue in these veins consisted of quartz plus siderite and ankerite rhodochrosite, barite, or, more rarely, fluorite, or combinations of thes minerals.

Most of the deposits of mineralized rock [2] in this area are veins tha have filled open fractures along extensive zones of structural disturb ance; these major zones are believed to be fractures that extend to great depth in the underlying rocks. Replacement deposits are less numerous but in some places have been mined. At a few places (such as the Gold King and Suffolk mines) many small veins cut the rock, and gold has been disseminated in the hydrothermally altered rock

[2] During this study of the geology, few samples were taken for assay, so that whether or not a particular "ore deposit" contained ore was not determined. For this reason, the term "mineralized rock" is used to describe the mineralized country rock, the vein filling, the gangue material, and the various combinations of ore minerals present.

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around them; one bedded deposit (the Crown Point mine) has been formed in metamorphosed limestone of the Pony Express member of the Wanakah. The east half of the southern section contains a large area of widespread intensely hydrothermally altered rock accompanied by disseminated metallic minerals that form an extremely low-grade deposit of large size.

Few detailed studies of the mines in the immediate area under discussion have been published. C. W. Purington reported on the economic geology of the area (Purington, 1898; Cross and Purington, 1899). In these publications, Purington discusses the mineralogy of the areas and mentions a number of the mines as examples of different general economic features he describes. Unfortunately, only one mine map (of the Gold King and Suffolk mine workings) was included in the report and it shows no geology. Several short articles a few pages long describe special features at some of the properties, but they contain little detailed description of use in the present study.

In contrast to the meager descriptions of the mining properties in the mapped area, the mines to the north and east have been described in many publications. M. E. Hurst (1922) described the rock alteration along the Smuggler vein. E. S. Bastin (1923) discussed the relations of primary and secondary silver minerals in the Marshall and Savage Basins area, in the Red Mountain district to the east, and in the Rico district. W. S. Burbank (1930, 1933, 1935, 1940, 1941) has discussed the economic geology of several areas to the north, northeast and east, and V. C. Kelley (1946) has described the ore deposits and mines of an area on the north side of the Silverton caldera. Most of these reports have been useful during the preparation of this report.

HISTORY

An excellent summary of the history of mining in San Miguel County up to 1923 is given by Henderson (1926) in his "Mining in Colorado," to which the reader is referred for details. Henderson bases his report on the early days of mining in large part on Burchard (1881–1885) and Purington (1898). The following paragraphs are a brief summary of Henderson's report as it applies to this area.

The location of the first claim, the Smuggler, in 1875, stimulated the interest of prospectors in the area covered by the geologic map (pl. 16), and shallow mines were developed quickly during the next few years. By 1878 rich silver ore from around Ophir was being packed over Ophir Pass to the smelter at Silverton. In 1879 ore from the Gold King mine was being sent to an arrastre in the vicinity of Ophir. The Alta, Palmyra, Silver Chief, and Osceola ore deposits were discovered about 1877 and were developed rapidly. By 1881 a mill had been built in Gold King Basin below the Gold King m In the following year mines were being developed even at altitude high as the Lewis mine, about 12,500 feet, the Summit, and the ' Top (the latter two on the ridge at the head of Gold King Ba altitude 12,400 feet).

The region attained real importance as a source of ore after Rio Grande Southern Railroad reached it in 1890. The railr went past Ophir Loop and a branch went past Telluride up to Smuggler Union Mill at Pandora. By 1898 most of the presen known deposits were producing ore. The use of electricity was wi spread in the district and most of the mines of any size were co nected by transmission lines to the power plant below Ophir Lo Thereafter the mining has continued to the present with perio ups and downs, controlled for the most part by metal prices. T mines operating on the argentiferous base-metal veins had conside able trouble in extracting the metals from the deeper unoxidized o when it was first reached. Much experimenting was done on millir and recovery of the metals, but the problem was solved only by th advent of differential flotation, and mining once more became profi able. Some rather large operations, which produced rather larg amounts of ore in the early days, now show little evidence of thei former existence as the workings are inaccessible and the mills an other buildings have been torn down or destroyed by the element particularly by great snowslides.

The largest mines in the area that are still partly accessible ar the Alta-St. Louis property, which was intensively mined from 190 to 1924, and from 1936 until the mill burned in 1948 (p. 288–293) and the Carbonero mine, which has had several periods of activity the latest being a project by the Defense Minerals Exploration Administration, which began June 2, 1952, and ended August 31, 1953. During the period 1938-42, and in 1947, at least some development was going on also at the following properties: the Dividend, Royal, Savage, Maryland, Silver Chief, Nellie, the western extension of the zone on which the Canton mine lies, and the Badger tunnel.

MINERALOGY

Little time has been given to a laboratory study of the minerals in the veins of this area, and consequently the discussion of the mineralogy is based in large part on field determinations and reference to previous publications (Purington, 1898; Bastin, 1923).

The following list is believed to include most of the important minerals in the veins and the hydrothermally altered country rock. Brief comments are given for some of them:

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PRIMARY ORE MINERALS

Native gold.—Much of the gold mined in the area is not visible to the naked eye and occurs either as very small particles, or intimately intergrown with, or included in, pyrite and the other sulfide minerals. In places it is present as visible particles, especially in the quartz veins that consist of little else but quartz and gold. It may occur as small specks, as wires, more rarely as very thin leaves, as much as an inch across, or extremely rarely as large irregular masses.

Gold tellurides.—Although the name of the principal town of this area is Telluride, gold tellurides are extremely rare in the area. One specimen, given to the author by Mr. Isaac Partenan, appears to be calaverite, but no telluride was identified in any of the mines examined below the zone of oxidation, nor are any reported by Purington (1898) or Bastin (1923).

Argentite.—Both primary and secondary argentite has been reported from the general area by Bastin. None has been identified by the author, although the mineral no doubt occurs in some of the mines that produced much silver, especially those along the Howard Fork.

Silver sulfosalts.—Bastin reports proustite and pearceite as primary minerals in the general are, but none was recognized during this study.

Galena.—Galena is a common constituent in all the base-metal veins, and is also the most widely distributed base-metal mineral sparsely scattered in veins otherwise barren of the base-metal minerals. It may occur in base-metal veins as solid coarse-grained masses, as intergrowths with sphalerite, chalcopyrite, or tetrahedrite, or as isolated grains scattered through the vein; in places it may comprise nearly all of some of the bands in crustified ores.

Sphalerite.—Sphalerite is present in many base-metal veins either as the iron-rich variety, marmatite, ("black jack"), or as the more pure dark greenish-yellow variety, ("rosin zinc"). It may be present as fairly coarse crystals, which in some places show free crystal faces in vugs, or as finer intergrowths in the other base-metal minerals. Sphalerite apparently is less common than galena throughout the region, but in places was abundant enough to have caused trouble in the days when the miners were penalized heavily for any zinc in the concentrate that they shipped to the smelters. Evidence for this remains in the form of sphalerite-rich parts of veins that have been left as pillars in the mines, and large amounts of sphalerite left in some dumps, where apparently it was discarded after being handpicked from the ore.

Chalcopyrite.—Chalcopyrite is fairly common in the base-metal ores, and usually is intergrown with pyrite or the other base-metal minerals, although it occasionally occurs as small masses scattered

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through the quartz, or more rarely, as crystals showing free face: vugs.

Gray copper.—Bastin (1923) reports both argentiferous tennan and argentiferous tetrahedrite in the general area, and Puring (1898) reports freibergite in the Terrible mine and San Juan mi near Ophir Loop. A gray copper mineral believed to be tetrahedı was identified during this study on the Lewis mine dump, in Alta and Crown Point mines, and in some of the veins in the sou western part of Bridal Veil Basin; it is believed, moreover, tl some probably is in most of the base-metal veins, and much of probably contains some silver.

Molybdenite.—A little molybdenite is present in the deposits of t valley of Howard Fork, either as scattered large flakes in coaı quartz, such as in the quartz-sericite pipe west of Chapman Gulc or as very fine particles smeared on joint faces, as in the Silver T mine.

Hubnerite.—A little fine-grained hubnerite was identified in tl Silver Tip mine, and more may be present in similar deposit associated with molybdenite.

Pyrite.—Although pyrite itself can hardly be called an ore minera it carries gold or is closely associated with gold in so many plac that it is described here. Like quartz, pyrite is found in almost a the veins that fill fractures, and it is widely disseminated throug the country rock along the walls of some of these fractures. In man places it can be found as discrete crystals in the country rock tha otherwise shows little effect of hydrothermal alteration. It is com mon in the zones of more intense hydrothermal alteration close to th fractures or the faults, which may or may not be filled with vein o dike material. The pyrite may be in masses, or as discrete grains o as crystals in vugs. The pyrite was deposited in several generations it may be found out in the country rock, or the outside of crustifiec veins, intergrown with the base metals, or as late-formed crystal: lining open vugs. According to local belief, the fine-grained pyrit is more likely to be accompanied by gold than the coarse-grainec pyrite, but this remains to be proved.

GANGUE MINERALS

Quartz.—Quartz is the most common vein mineral in the area south of Telluride. It fills fractures or parts of fractures of all different orientations and makes up part of every type of vein, excepting a few calcite veins. Quartz was introduced at several times during mineralization, and it varies widely in appearance. The deposition of most of the different types is separated by fracturing and reopening of the

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vein. The chief habits of quartz are listed below. approximately in the order in which they formed:

a. Fine-grained quartz replacing the country rock.

b. Fine-grained waxy or chalcedonic quartz representing silicification of gouge or country rock close to a fracture.

c. Massive, clear or milky quartz in veins (the "bull quartz" of the miners).

d. Finer grained sugary quartz in veins.

e. Crystals of quartz, (as large as half an inch long) usually clear, in comb structure.

f. Large crystals of quartz (as much as 6 inches long), clear, milky or amethystine, in vugs.

g. Very fine crystals (drusy quartz) lining cavities and covering the two previous types.

h. Very fine grained quartz, perhaps in part chalcedonic, variously described in the field as onion quartz, cauliflower quartz or botryoidal quartz, in vugs.

More careful study of the different types of habit of the quartz and much assaying would be necessary in order to identify the types of quartz with which gold is associated, either free or in pyrite. In general, however, gold appears to be associated more commonly with the sugary quartz, the fine crystals in comb structure and the drusy type of quartz.

Carbonates.—Siderite or ankerite forms irregular masses in many veins containing the base metals; generally it was recognized only underground in the accessible mines, but is believed to be almost always always present in the veins containing significant amounts of galena, sphalerite, chalcopyrite, or tetrahedrite. The siderite or ankerite was deposited at an early stage in these veins. Hereafter in the report this early formed carbonate will be called ankerite although in places it may be siderite.

Some rhodochrosite was seen underground, and in all probability it is more common than it appears to be from surface exposures. This is true especially in the veins in and close to the Ophir Needles intrusion where a large amount of black manganese oxide is in the weathered zone of those veins.

Calcite is present as a late-formed mineral in a few veins, either as solid masses or as crystals lining vugs; a few veins consist only of calcite bordered by slightly altered wall rock. The mineral is common in the altered wall rock along other types of veins, mostly in a zone outside the sericitized zone that occurs close to the veins.

Barite.—Barite is present in some of the veins, usually intergrown with the base-metal minerals. It is associated in places with quartz

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and fluorite in the "Millionaire"-type veins, and in places appear to have been leached out by hydrothermal solutions, leaving cavities shaped like barite crystals; some of these cavities are lined with drusy quartz.

Fluorite.—Although generally sparse, fluorite is present in a few veins. It is most abundant in the veins around the lower end of Bridal Veil canyon. The fluorite generally is fairly coarse grained and light green. In places it has been leached out and the resulting cavities are lined with later formed fine-grained quartz.

Gypsum.—Gypsum is present in the Carbonero and Panama veins of the Carbonero mine. It is probably also present in other mines on the north side of the valley of Howard Fork, but was not identified. With quartz it makes up the sparse gangue accompanying the base-metal sulfides of the Panama vein, and is associated with quartz, some rhodochrosite, and calcite in the gangue of the Carbonero vein.

Sericite.—Sericite, with quartz and pyrite, is abundant in the hydrothermally altered country rock along almost all the veins. Hurst (1922, p. 681–685) gives an excellent description of this material as he found it in the wallrocks of the Smuggler vein. It is widespread in the large area of altered rocks on the flanks of the valley of Howard Fork. There, also, coarse sericite and quartz almost completely replace the breccia in breccia pipes. One such pipe, in the gulch west of Chapman Gulch, was so completely replaced that it was labeled a quartz-sericite pipe.

Clay minerals.—A pure white or light greenish-gray claylike material is present in the veins in places, which suggests that it is a primary mineral rather than the result of weathering; this mineral is probably dickite (Ross and Kerr, 1931), but no attempt has been made to identify it in the laboratory. Fairly massive light-brown to nearly white material from the strongly altered area on the north side of the valley of Howard Fork was identified as allophane by C. S. Ross of the U.S. Geological Survey (written communication).

Kaolinite is common in the altered country rock along the veins at the surface and is believed to result from the weathering of the feldspars in the rock, probably intensified by the sulfuric acid resulting from the oxidation of the ever-present pyrite.

Adularia.—Scattered small well-developed crystals of adularia occur along some narrow gold-bearing fractures. More careful microscopic work might prove it to be more abundant than it appears to be from a superficial examination.

Secondary sulfides and sulfosalts.—In this region of great relief, erosion is so rapid that there is little chance for the formation of any appreciable amount of secondary sulfides and sulfosalts (Bastin,

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1923, p. 95). Aside from a little bornite(?), chalcocite, and covellite, no secondary sulfides or sulfosalts were recognized during this study. Bastin (1923) found that some proustite and some argentite in the silver-bearing veins are secondary.

OXIDIZED ORE MINERALS

Native silver.—Bastin (1923) reports that wire silver occurs with argentite. It undoubtedly occurs within a narrow range of the surface in the veins rich in silver. None was seen during this study.

Copper bloom.—Green and blue copper minerals (probably mostly malachite and azurite) are present in the oxidized parts of veins carrying copper.

Cerussite and anglesite.—Cerussite and anglesite are probably common in the oxidized zone of the veins that contain lead but were recognized in only a few outcrops of veins.

PARAGENESIS

The paragenetic sequence of minerals in the veins as outlined below is based predominately on field observation with only a minor amount of microscopic study. Much more detailed work will be necessary to work out specific mineralogic relationships, particularly between the various sulfides.

The age relationships of the different forms of quartz were determined on the basis of field observations, and the sequence of deposition of the other gangue minerals and the ore minerals correlated roughly in this general outline. The following sequence of events was deduced during the fieldwork for one of the barren(?) veins north of the Weller mine.

1. Formation of a fracture
2. Silicification and pyritization of the country rock
3. Fracturing
4. Deposition of large quartz crystals and pyrite
5. Fracturing
6. Deposition of fine vuggy comb quartz
7. Deposition of calcite and "onion" quartz in the vugs

This sequence of events, with local variation, applies generally to the whole South Telluride area. The so-called bull quartz and the fine waxy quartz formed during intense silicification were deposited before the fracturing under 3. In the base-metal veins sugary quartz, chalcopyrite, sphalerite, galena and tetrahedrite probably were formed at stage 4, accompanied locally by barite, ankerite, rhodochrosite, fluorite, or gypsum. Gold appears to have been deposited with the fine comb quartz of stage 6, but some may have been deposited earlier or later.

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STRUCTURE OF ORE DEPOSITS

The individual veins occupy faults and fractures that constitu parts of more extensive structural zones. Only the larger of the structural zones have had mines developed along them. The Cham pion-Dividend zone (pl. 17) is exposed for about 15,000 feet and co tinues east-southeastward on Burbank's map (1941) for at least 3,00 feet more. Some of the zones that strike northeast across the easter section and swing south as they approach the Howard Fork valle have a length of more than 20,000 feet, although they are not con tinuous over this length. They are known to continue a considerabl distance northeast of the mapped area. The zones that extend acros Bear Creek in a westward direction are exposed for as much as 8,00 feet, as are some of the northwest zones in the southwestern sectior The longer zones of fracturing probably continue down into the pre Tertiary rocks.

The individual veins are not nearly as long as the major structura zones in which they occur. The Alta-St. Louis mine (the only large mine studied in detail) develops veins as much as 2,000 feet long. shorter veins, not exceeding a few hundred feet, occur throughout the area. The shorter veins generally have been little developed by mining, except where they constitute a closely related group of veins arranged in echelon. (See below.)

Ore shoots in the Alta-St. Louis mine have been stoped continuously in one place for as much as 1,500 feet, but most of the ore shoots on veins in the area are much shorter. The individual ore shoots in the Nellie mine, for instance, are only a few tens of feet long.

Many veins are arranged in echelon in the parallel fractures of structural zones; the echelon arrangement may take place either along the strike or down the dip. This feature is best illustrated underground on the map of the Nellie mine (pl. 20*J*). There, echelon vein segments are spaced only 3 to 4 feet apart, so that the miners, in drifting, would break across from one fracture to the next, after leaving an ore shoot. At the Fairview mine, on the other hand, on the surface it can be seen that as one vein dies out westward, another, 10 to 20 feet north, increases in width, reaches a maximum width of between 2 and 3 feet, then dies out. In some places a few weak altered cross fractures join the successive veins together, in other places a narrow stringer of quartz bends over to a northwest strike and joins the next vein to the north. The fact that this feature was apparently not appreciated during development of the mine is shown by the highest level of the mine (pl. 20*H*), where one fracture was followed a long distance, and no crosscutting done to explore the parallel fractures. This echelon arrangement of the veins (and ore shoots as well) is

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probably quite common, although perhaps not everywhere so pronounced as at the above-mentioned two mines. The Nellie-Wasatch zone also shows a large-scale echelon offset to the south updip, across the high ridge between Bear Creek and La Junta Basin. (See pl. 16.)

Ore has been mined in the area from as low as the Canton mine, altitude 9,580 feet, in the Cutler formation, to as high as an altitude of 12,900 feet in the breccia member of the Eureka rhyolite of Palmyra Basin. In upper Bridal Veil Basin, mines at altitudes above 12,500 feet in flows of the Burns latite have yielded ore, and in the basin of Blue Lake ore has been stoped from the Potosi volcanic series at about the same altitude.

Neither the altitude at which a vein is found nor the chemical character of the wall rock is a factor in determining whether a vein contains sufficient valuable metals to be minable. The two important facts in forming minable veins are believed to be the fracturing characteristics of the wall rocks and the time of fracturing; fracturing took place several times in the area, and when fractured ground was available to solutions containing valuable metals, metalliferous veins were formed.

The formation of the veins and the ore shoots within them was strongly influenced by the type of fracturing that took place in the different lithologic units in the area, and by the changes of dip of the fractures. The most favorable units, on the whole, were those of intermediate strength and relatively coarse grain. Units having these characteristics are the San Juan breccia, the breccia members of the Eureka rhyolite, and the Burns latite, the conglomerate of the Telluride formation, and the conglomerate and sandstone of the Cutler formation. The San Juan breccia contains the most ore in the South Telluride area both because of its favorable characteristics under deformation and because it is the thickest of any unit. The Entrada sandstone might have been relatively favorable, but it is so thin and lies between such unfavorable units (the Dolores and Wanakah formations) that there are no known ore bodies in it.

Relatively weak units were unfavorable because fractures did not stand open long enough for veins to form in them. The Dolores, Wanakah and Morrison formations are of this category. The Pony Express limestone member of the Wanakah might be considered an exception. The few veins seen cutting this unit, however, do not change appreciably in width, nor are bedded deposits found in it as happens in the Ouray district (Burbank, 1940, p. 211), except for the Crown Point mine (pl. 21*I*); there a replacement deposit has formed in the metamorphosed Pony Express limestone member.

The stronger units form only narrow fractures when deformed and therefore contain only narrow veins, if any. The flows of the Eureka

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rhyolite and of the Burns latite are therefore relatively unfavora[ble] both as to fracturing characteristics and thickness.

The members of the Potosi volcanic series are in general relativ[ely] unfavorable host rocks, although a few small mines have produ[ced] ore from the lowest member in East Basin and in Bridal Veil Bas[in]. The reason seems to be that faults and fractures that extend up in[to] this formation split into broad zones of fracturing, and the hyd[ro]thermal solutions rising into these ramifying channelways caus[ed] widespread alteration rather than definite veins. Only rarely we[re] vein minerals deposited in any of the narrow fractures, and whe[n] this happened the minerals were usually limited to quartz cryst[als] and minor amounts of pyrite. This splitting of fractures in t[his] formation may have taken place because of nearness to the surfa[ce] and the resulting light load rather than because of the relati[ve] strength of the formation. The widespread areas of alteration, whic[h] include silicification and the formation of disseminated pyrite an[d] clay, have formed extremely large deposits, probably much too lo[w] grade for mining in the foreseeable future.

The formation of ore shoots is controlled mainly by two factor[s]. First, openings are widest in the steeper segments of normal fault[s] of variable dip. Although there is little actual information availabl[e] about the plunge of ore shoots in the area, it appears that where th[e] change of dip plunges along a vein, the resulting ore shoots on th[e] more steeply dipping part of the vein plunge similarly. Secondly the fractures must be open at the time when solutions containing metals are available to traverse them. For this reason, fractures that have been reopened many times are more liable to have ore shoots along them than those which opened only a few times. In places, the earlier formed base-metal deposits have been enriched by being reopened at a time when gold-bearing solutions were available. This was seen at one place on the fifth level of the Alta vein, where a later-formed quartz vein containing gold cuts through an earlier quartz-ankerite vein bearing galena, chalcopyrite, and tetrahedrite. The same thing undoubtedly has occurred at many other places.

TYPES OF ORE DEPOSITS

Most of the ore produced in the South Telluride area has come from veins that fit the old definition of "true fissure veins"; that is, the material in the veins has been deposited in large part in openings along fractures. Successive movements along these fractures have resulted in repeated reopening, and therefore deposition of the vein minerals in successive stages was common, and the veins generally are crustified or banded. Hydrothermal alteration has affected the walls of all the veins of any importance, but only rarely was any

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